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2018 PROGRAM
EXECUTIVE SUMMARY

Introduction: The DoD 2018 Arctic Science & Technology Synchronization Workshop, which was co-sponsored by NORAD USNORTHCOM and the DOD Under Secretary for Research and Engineering (OUSD(R&E)) Human Performance, Training, and BioSystems (HPTB) Directorate, sought to establish, align, and coordinate military-wide science and technology needs and requirements pertaining to the Arctic. The Workshop aimed to further the DOD desired end-state for the Arctic, as laid out in the 2016 DOD Arctic Strategy: “a secure and stable region where U.S. national interests are safeguarded, the U.S. homeland is defended, and nations work cooperatively to address challenges”

The Workshop was attended by 120+ participants from across DoD, academia, and Allied nations. Participants comprised a mix of military operators, science policy experts, and science & technology professionals from academia, industry, and government. The Workshop consisted of presentations followed by time for questions, and was concluded with break-out sessions dedicated to in-depth discussions. In general, Workshop themes and outcomes clustered into the fields of a) domain awareness, b) humans and materiel, and c) infrastructure.

Domain Awareness: The greatest needs in domain awareness, according to participants, revolve around maritime operational needs for navigation. Advances need to be made in measurements of ice thickness and extent, as well as the ability to transmit real time, actionable data products for navigational use. Other navigational challenges include fogging, patchy ice coverage, and insufficient bathymetric charting. Advancements in sensor development is also important, both for sensors that are cold-hardened as well as autonomous sensors able to provide more comprehensive Arctic coverage over longer periods of time. Radar and communications capabilities are continuous pressing issues requiring attention.

Humans and Materiel: Human performance elements for Arctic operations could be strengthened. In addition to the lengthier training times that should be accorded to Arctic operators, better gear, particularly multi-layer cold-weather clothing ensembles and boots with liners, would contribute to warfighter readiness in the Arctic. As the Arctic changes, equipment needs will change as well, and requirements for cold-weather vehicles should be analyzed.

Infrastructure: Infrastructure requirements in the Arctic center around the need for expeditionary infrastructure that is modularized, transportable, easily set up, and constructed from local materials.

Outcomes: A final theme echoed throughout the Workshop: the need for multiple, systematic lines of communication between DoD operators, researchers, and policy-makers, to ensure the development of requirements and solution sets fit to operator needs. Feedback sheet input indicated high participant satisfaction with the Workshop and interest in a following Workshop, slated for 2020.
INTRODUCTION

Above the 66°33’ latitude north, and by any definition of the Arctic, in fact, science and technology efforts cannot be easily disentangled from operational mission sets and security concerns. Rather, science and technology underlay vital elements of military engagements in the Arctic, from survival to overmatch, and can act as an enabler in many other dimensions, a point well elucidated by LTG Hoover during his opening address at the 2018 DoD Arctic Science and Technology Synchronization Workshop.

According to LTG Hoover, Arctic science and technology needs pertaining to NORAD-USNORTHCOM cluster into a number of primary areas:

1) Domain awareness and communications
2) People and materiel
3) Infrastructure

The 2018 Workshop structure in general adhered to similar topical areas, and considered their applicability across space, air, land, and sea. Beyond its broader aim to give Arctic operators and researchers with DoD ties a space to connect and trade insights, the Workshop specifically aimed to identify challenges, areas of opportunity, gaps, capabilities, and potential requirements in an interdisciplinary, Joint-Service space that was also open to collaborating academic partners. As geopolitical, economic and environmental conditions continue to shift in the Arctic, DoD needs may subsequently also shift. The Workshop was a chance to examine these potential shifts, to compare needs and approaches across the Services, and to identify opportunities to advance Arctic-relevant science and technology across the military and its partnerships.

Workshop Description in Brief: Held at the U.S. Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH from 16-18 May 2018, the Workshop consisted primarily of presentations followed by time for questions and answers. Breaks, a poster session, and social sessions enabled networking, problem-solving, and continued discussion. Time was also allotted for more in-depth facilitated discussions of main topical areas, summaries of which have been included in this report. The Workshop was the third in a series, the other Workshops being held in 2014 and 2016, respectively.

Past Workshop Findings: Previous Arctic Science & Technology Synchronization Workshops were sponsored on both occasions by NORAD USNORTHCOM. In 2018, the DoD joined NORAD USNORTHCOM as a sponsor to add a broader focus and to build on previous findings, which highlighted:

- Continued Russian expansion in the Arctic and the growing interest in the region from other sovereign nations
- A lack of useful, highly accurate climate models as well as difficulties in weather and climate prediction
- Increasingly strong currents, increased icing and sea spray, and faster-moving ice
- Requirements needed for surface operations
- Advances and interest in unmanned vehicles
- Investigation of renewable energy sources
- Advancements in hyperspectral research and in nano-technology for concrete hardening

The 2016 Workshop presented an overview of current science and technology efforts with Arctic relevance. Issues brought up then continue to maintain their relevance in 2018, namely heavy fog and icing, unpredictable iceberg movement and cracking, a lack of sufficient ice-hardening for airborne and waterborne
assets, ongoing challenges with sustainment and resupply, and conditions difficult for ground troops to surmount, given their current equipment and levels of training.

**The Arctic in Brief:** As most presenters vividly illustrated, the Arctic is a region of rapid and unpredictable change. Region-wide melting of once thick and persistent ice has opened up relatively ice-free channels for unprecedented levels of maritime navigation, which has sparked increasing Russian and Asian interest in new, potentially cost-efficient shipping routes. Ice melt, decreased snow cover, and permafrost thawing could also unlock access to extensive resources that were previously unfeasible to develop.

As more commercial shipping, industrial developers, and tourists occupy the region, risks of accidents, oil spills, and mass casualty events also rise, and are not manageable with the current levels of local resources. The region’s increasingly severe storms, coupled with more severe fogging incidents, adds increased navigational complexity to an already challenging operating environment. In short, the region is changing, and, upon examination, NORAD USNORTHCOM as well as DoD will reexamine their priorities as necessary.

**U.S. Military Responsibilities in the Arctic:** While the Arctic region is not the geographic area in which the U.S. military is most active, Arctic priorities are still very present in DoD thinking and policy. In remarks prepared for his confirmation hearing Secretary of Defense James Mattis wrote, “The Arctic is key strategic terrain… I will prioritize the development of an integrated strategy for the Arctic.” General Terrence O'Shaughnessy, Commander, NORAD USNORTHCOME, has mentioned domain awareness, long-range secure communications, scalable infrastructure, strategic planning, and the ensuring of future capabilities as his priorities in the Arctic, and has said he will place strong emphasis on his role as the DoD Advocate for Arctic Capabilities. General Neller has said that the Marines “have gotten back into the cold weather business. We can’t assume that we’re going to fight in a desert, it’s not going to be a temperate climate, it could be in an Arctic climate…we’re moving in the right direction and doing our best to get more deployments for training to Alaska to take advantage of the terrain and the climate."

DoD’s most recent Arctic Strategy emphasizes the area’s importance while also pointing out the effects and implications of its rapid changes. The DoD’s goal for the Arctic, as detailed in the 2016 *DoD Arctic Strategy* as “a secure and stable region where U.S. national interests are safeguarded, the U.S. homeland is defended, and nations work cooperatively to address challenges,” is expected to continue in the near future. The Air Force is composing its own Arctic Strategy to highlight area priorities. And the Navy’s Ocean Battlespace Sensing Department has pinpointed U.S. Arctic Region Challenges, specifically identifying harsh operating environments, communications needs, satellite sensor need, and strengthened human performance factors.

**Potential Sources of Tension in the Arctic:** Due to contracts and pre-established sovereignty claims, US NORTHCOR analysts anticipate that conflicts over petrochemicals and rare earth metals in the region will likely remain low in the very near future. Biomass, instead, is currently the most accessible and potentially contestable Arctic resource. As Arctic fish stocks shift, the fishing agreements and bans currently in place may not prove sufficient to prevent disputes or illegal fishing.

Russian and Chinese influence in the region is steadily increasing. The fact that 20% of Russia’s GDP comes from their Arctic region explains much of their regional investment. By virtue of having already built infrastructure, they possess the advantage of readiness, as it takes considerable time and expense to build in the Arctic. Russia also exercises overmatch in surface naval operations with their Northern Fleet and in the airspace due to their operating bases. Finally, they possess ground advantages with permanently Arctic-stationed troops who are already trained to operate in the region.
China is currently writing its own Arctic Strategy, and has demonstrated its intent to continue investing in the area, as have several other Asian countries. As interest and investment in the Arctic continues to grow, its geographic isolation will decrease.

**International Arctic Expertise:** Other Arctic nations offer the United States valuable expertise, perspectives, and opportunities for collaboration on Arctic science and technology. Finland, for example does not have special cold weather military requirements, as the Arctic is such a routine operating space for them that all their military must be cold-weather compliant. Through the European Maritime Capabilities in the Arctic project, Finland is expanding its maritime polar capabilities, multi-nation cooperation on satellites, and work on risk and stress. They are currently establishing an Arctic Knowledge and Data Management Cell, and also conduct regular Arctic education sessions, trainings, exercises, and evaluations. Similarly, Norway conducts regular military exercises in the Arctic, and has recently requested the stationing of 300+ additional U.S. Marines close to the Russian border. Canada has prioritized Arctic science and technology for future investments, and has presented a number of opportunities for U.S./Canadian collaborations.

**2018 Workshop Findings in Brief:** 2018 Workshop discussions and findings clustered into three main topic areas: 1) Domain Awareness, 2) People and Materiel, and 3) Infrastructure. Overarching themes were also present, and included the need for better communication channels between: a) Operators and academics/researchers, b) the Services, and c) DoD and non-DoD entities with Arctic interests. Each of these topic areas and overall themes are discussed in turn below, and a comprehensive list of gaps, opportunities, and recommendations is included in the appendix.
DOMAIN AWARENESS

**Common Themes**: Domain awareness, particularly in the maritime sphere, repeatedly surfaced as a primary concern, both in discussions of U.S. defense and in common concerns shared with Canada. Chief among the domain awareness needs mentioned was the need for:

- Bathymetric surveying of Arctic waters for navigation
- A more comprehensive, real-time-enabled understanding of ice thickness and drift patterns.

While discussions of domain awareness for surface and sub-surface maritime operations dominated, domain awareness needs within the atmospheric and terrestrial regions were mentioned as well, with participants emphasizing the interactions between these regions as well as the need for domain awareness informed by multi-disciplinary and cross-domain approaches. Overall, domain awareness was deemed vital for both scientific and operational purposes.

**Short and Long Term Aims**: In the Arctic, domain awareness endeavors are directly operational applicable, but also inform long-range and risk reduction strategy development. Domain awareness provides a better understanding of what lies above and beneath the waves, and is essential for warfighter safety and mobility. Technology for domain awareness supports both environmental analysis and operator decision support tools, including sea ice and weather forecasting tools. Recent advances in this field include cube satellites and unmanned aerial vehicle (UAV) development and use, but significant data transmission and communication challenges still exist and continue to impair both U.S. and Allied countries’ domain awareness efforts.

- Recommendation: Increased investments in aligned data sensors with long-term data potential

**Risk Management**: Domain awareness includes tracking of Arctic-specific hazards and risks inherent in the region as well as recognition of how humans will anticipate these risks. Due to an influx of people to the area and to the area’s austerity and the rapidity of the shifts it is now undergoing, new arrivals may not be adequately prepared to safely inhabit the Arctic. Collaboration is key, and agencies such as the Arctic Domain Awareness Center’s (ADAC) has cited collaboration as a contributing factor to domain awareness and risk reduction efforts.

**Canadian Domain Awareness**: All domain situational awareness is also a shared priority in Canada, which is dedicating $133 million for a science and technology program that runs until 2020 to inform future Canadian Armed Forces surveillance capabilities, with a particular focus on Arctic joint intelligence, surveillance, and reconnaissance. Canadian specialists partner with the U.S. Air Force Research Laboratory (AFRL) and the Naval Research Laboratory (NRL) on multiple science and technology projects, adopting an approach calculated to de-risk unproven technologies. Aerospace warning systems, maritime surface surveillance, sub-surface surveillance, and sensor/information mixes are particular priorities. In addition, Over the Horizon Radar (OTHR) could be viable for use in Northern surveillance, and could support the North Warning System, a joint U.S.-Canadian system.

**Air Operations**: Atmospheric conditions and how they influence maritime patterns are not well understood. While work is ongoing on multiple atmospheric models and already involves collaborations with multiple federal agencies and divisions, mutually beneficial work could be conducted within a more holistic and collaborative framework, as identified by Workshop participants and presenters. The connections between meteorology and oceanography, for example, could be better developed, including how phenomena like the aurora borealis and geomagnetic storms affect satellite communications. Research is also being conducted in
polar cyclones and in high atmospheric storms to reduce forecasting errors and to assist with operational communications.

**Maritime Operations:** Ice presents a serious hazard to ship navigation, and demands adequate tools and expertise to properly anticipate is thickness and extent. The Office of Naval Research (ONR) has been responding to emerging Arctic maritime interests with coordinated research projects, including the Arctic and Global Prediction Program and the Arctic Mobile Observing System (AMOS). ONR programs also research ocean dynamics and low-frequency signal propagation under ice and in sea water columns via a variety of projects, such as the Canada Basin Acoustic Propagation Experiment (CANAPE) and the Stratified Ocean Dynamics in the Arctic (SODA) effort, resulting in data collection and modeling that will assist with pressing questions on Arctic ice and seawater developments and movements.

Even when adequate and actionable sensing data is collected for either modeling purposes and/or the development of operational navigational products, data transmission and storage between all relevant stakeholders continues to present a barrier. Challenges stem from the technical problems of sustained connectivity—particularly for data streaming, e.g. sending real-time or high-volume data, in high latitudes as well as interoperability issues between the various data platforms being used.

Additional factors also complicate data transmission. For example, allied navy partnerships permit better iceberg detection, but not all ships or seamen are trained to operate in the Arctic, although mission redirects may result in them being unexpectedly stationed there. Older technologies for weather prediction, such as the Weather Fax receiver, are still being employed under some circumstances, either when they are more readily available in a particular location, or when service members may lack awareness of alternative options. Having multiple communication options at hand would add robustness to current capabilities.

**Maritime Exercises:** Multi-agency exercises such as Ice Exercise (ICEX) have been an excellent way to test research and communication capabilities. ICEX 2018 gave researchers a chance to practice their skills in measuring snow and ice prior to landing aircraft, as well as in predicting ice floe fracturing on a micro-scale level, all of which have been deemed important priorities. Overall, the exercise helped prove the desirability of increased vehicular automation, of equipment with enhanced cold-weather functionality, of sensors more resistant to frost accumulation, and of the need for tents better designed to handle condensation and heating issues.

**Maritime Communications Needs:** ICEX 2018 also highlighted the imperative need for affordable, secure communications designed specifically for cold weather and high latitudes. Current radios re-designed to align with CENTCOM specifications now limit wavelength customization that had previously permitted operators more bandwidth options for high-latitude data transmission. Technology relying on fixed antennae has generally not been performing well at high latitudes, due to a lack of clarity regarding optimal positioning angles. Hand-held phone technology has proven quite vulnerable to chilling, requiring better heating options or redesigned clothing that will place mobile phones closer to the body to maintain warmth. At Arctic Edge, some groups were able to use RO/VTC and encrypted radios north of the Brooks Range, as long as they were set up by experienced communications technicians.

- **Recommendation:** Communication/Joint exercise opportunities between different operational communities to share knowledge on optimal communication strategies

**LC130 Operations:** The National Science Foundation (NSF) and New York Air National Guard 109th Airlift Wing currently collaborate on completing LC130 missions in the Arctic that support ongoing research and operations. Again, the need for accurate, actionable navigational data predominates. Data on ice thickness and crevasse location is mission critical, both for freedom of navigation and for estimations of what areas will
safely support an LC130’s weight. The current data being used are out of date and were originally calculated for the C130, not accounting for the additional weight of an LC130. Current LC130 radar capabilities are inadequate, as do the digital terrain elevation models used to identify safe landing sites. Improvements in remote sensing data would decrease ground crew time and the work required to find suitable landing zones, particularly in high-stakes situations when rapidly changing local conditions necessitate rapid responses underscored by fuel limitations. LC130s themselves present opportunities for increasing domain awareness, as they can carry sensing equipment when not carrying other loads.

**Maritime Data Quality and UAVs:** The quality of data content, not just the difficulty of transmitting it, also deserves consideration. Bathymetry is still inadequate in many areas of the Arctic, with charting and mapping needs ranked as a high operational priority. Inadequate navigational aids could cause unnecessary collision risks, particularly in conditions of high fogging. One promising option to improve the quality and scope of maritime-relevant data is the use of Unmanned Aerial Vehicles (UAVs) for ice detection, as is currently being tested in the ONR SODA project. As UAV endurance and range increases, their utility in bearing sensors and supporting domain awareness will increase. Existing UAVs, such as Global Hawks and Gray Eagles, could already be deployed for data collection and navigation if loaded with improved sensor packages.

Commercial advances in the UAV field have been developing new capabilities and merit consideration for future DoD partnerships. Off-the-shelf UAVs with non-U.S. parts are not always usable, however, since any UAVs used will need to fit requirements for secure data transmission. Other challenges are posed by operating in cold, dark environments with poor GPS instruction and poor satellite coverage; airframe icing; pilot exposure risks; battery life and performance degradations; and limiting FAA regulations.

**Other Maritime Domain Awareness Efforts:** Additional U.S. domain awareness projects include the Maritime Domain Awareness RFP, long range autonomous underwater vehicle (LRAUV), modeling with pan-Arctic resolution to the 1-km level to assist with ice lead detection and navigation, bathymetric surveying, weather forecasting, crisis response, low cost sensors and smart cameras, and the CubeSat Antenna Farm Experiment (CAFÉ). Each of these endeavors could push domain awareness efforts forward, but should be coordinated to reduce redundant efforts.

In addition to weather and ice navigation concerns, maritime operators at the Workshop were advised to be conscious of the overall environment, including local animal migrations. One particular capability need is an improved capacity to track marine mammals during migration to aid in mission planning in coordination with Alaska Native populations and with subsistence hunters to support local food security and community relations.

These questions are not confined to U.S. concerns, but are shared across the U.S.-Canadian border. During its decades of Arctic research, Canada has emphasized deep water research, frazil ice impacts, and icebreaker testing. They also produce software and knowledge-based products for numerical modeling, including ice pressure field modeling, ice modeling, and forecasting for both commercial and military applications. Canada’s National Research Center (NRC) carries out a joint research project with Greenland to track icebergs using radar and satellite reconnaissance. Multiple Canadian projects will be furthering Arctic sensing, including under-ice bathymetric sensing, and surveying for situational awareness through CANAPE and CABAGE, which share data with the U.S. and are, respectively, directed at oceanography and undersea mapping. The NEPTUNE Ocean Observatory-based acoustic array will also contribute to U.S. awareness. For both countries, tracking bergs within sea ice still presents a formidable challenge.

- Recommendation: Systematic communication channels around these issues among the Services would help exercises and training proceed more smoothly and with more comprehensive shared
knowledge, ultimately aiding mission success. One solution could be the broad Service-wide implementation of a program similar to ONR’s Science Advisor Program. Science advisors interface between the military and S&T communities, and could aid in information-sharing and knowledge retention while building networks in the Arctic research community.

**Terrestrial Operations:** While maritime and air operations currently lead in the Arctic, terrestrial-based operations also have pronounced needs for better domain awareness. Dismounted units require better information on local conditions and better access to cold-hardened equipment that is resistant to frost, condensation issues, brittleness, and other impacts of cold-weather operations.

Land-based missions are subject to geologically dynamic conditions such as earthquakes and volcano eruptions. In general, the Alaskan Arctic presents its own challenges due to both its underlying magma veins and continental plate seams as well as to the changeability of its thawing permafrost. Countering these potential disruptions takes developed capabilities in atmospheric science, remote sensing, seismology, permafrost dynamics, snow variability, and space. Wildfire monitoring will begin playing a larger role as permafrost continues to thaw and create drier areas of land that are more susceptible to damage by fire.

While military assets in Alaska can already collect data in these domains, and already collaborate with agencies such as the United States Coast Guard (USCG), National Guard, NSF, and NASA, room for capabilities growth exists. Northern sites are also suitable for missile testing, tsunami detection, and for developing infrasound explosion sensing and geophysical detection of nuclear signals. Academic facilities permit rocket launching, LIDAR experimentation, and work with herder-burner tanks to explore oil spill remediation. The High Frequency Active Auroral Research Program (HAARP), a former DoD asset, still offers powerful Arctic capabilities and could be used to create an ionosphere or as a powerful transmitter for emergency broadcasts.
Domain Awareness Challenges Identified
- Sharing actionable real-time data for navigation and domain awareness
  - Dealing with data storage capacity issues
  - Data transfer challenges
- High frequency radar capabilities do not operate in polar conditions, and face additional problems with the Arctic ionosphere’s interference.
  - Plasma in the region makes it difficult to transmit radar
- DoD may not be able to match the pace of UAV development, and may need to seek partnerships with industry
  - Data security issues are a challenge

Domain Awareness Recommendations Made

Communications
- Operators should drive research and contribute to requirements and capabilities documents to result in products and policies with greater relevance
- Achieve improved operational communications for transmitting domain awareness information
- Establish a central hub for documents related to Arctic/international participation for knowledge sharing
- Transmit research findings among an increased number of stakeholders
- Appoint science advisors in DoD departments to aid in information transmission S&T and operational communities

Modeling
- Share non-tactical data for modeling purposes with international partners and other agencies
- Assemble and use comprehensive, robust data sets to enhance model development
- Identify robust model outputs to inform operations
- Conduct basic research on modeling activity to extend Arctic range predictions
- Construct high fidelity models for high-resolution atmosphere, ocean, and sea ice patterns

Operational
- Increase capabilities to detect snow and ice thickness and stability prior to landing aircraft
- Predict floe fracturing on a micro-scale level for safer operations and exercise
- Better training for operators who might be deployed to the Arctic
- Fly UAVs routinely under realistic Arctic conditions and ice-harden their systems
- Develop DoD work with the National Oceanic and Atmospheric Administration (NOAA), the Department of Energy (DoE), and the Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) to develop UAV CONOPS
- Track marine mammals in accordance with their changing migration patterns and relevance to hunting
PEOPLE AND MATERIÉL

The intense DoD focus on developing equipment for operating in desert environments for the past 15 years has resulted in a capabilities gap when it comes to cold-weather gear and equipment. Equipment has not been modernized for extreme cold or for high altitude mountainous regions, which could pose a threat to readiness. Given the uniqueness of Arctic conditions, the training, equipment, and medical care afforded to service members operating in the region must often be unique. Having the right kit and training at the right time is not only convenient, but absolutely essential for survival in the extreme conditions and austerity of Arctic environs. And equipment, even if it is designed for cold weather performance, is useless if it does not perform reliably under actual Arctic conditions. These considerations are important, given the possibility of increased troop involvement in the Arctic and the need to reliably project appropriate force.

Requirements for cold-weather operations are complicated by the fact that gear in this region does not typically fit into the one-approach-works-for-all model. In fact, National Guard and Special Forces operating in the Arctic report higher success when their members are able to tailor their gear to their own individual needs and preferences.

While the U.S., Canada, and Europe do not amass nearly the sheer numbers of Arctic-trained troops Russia can reportedly field, they are still invested in an increased Arctic presence. Specifically, the Marine Corps identified several regions for joint operations with Norway last year, and have recently been requested to send 300+ more Marines to Norwegian territory. At the 2018 ICEX, Marine instructors were trained to, in turn, provide Arctic training to other amphibious units. The demand signal for Arctic-trained engineers has also increased, as evidenced by the interest from China, Korea, Pakistan, and India in hiring engineers with Arctic expertise. These personnel are already in short supply for Greenland and Denmark.

Testing Needs: Requirements so far have typically neglected to specify a comprehensive and accurate range of conditions under which gear and equipment should perform. Some requirements, for example, have listed -20°F as the lowest temperature gear must be tested at, but Arctic temperatures can plunge to -80°F, and can easily remain well below -35°F for extended periods of time. Operators reported that unexpected gear failures began to peak at -30°F and below. Equipment and gear, therefore, must be tested under realistic conditions and for realistic durations of time, particularly given the severity of the consequences that can arise, should unanticipated gear failures occur in operational conditions. Additionally, gear is not being designed with all conditions in which it might be expected to operate in mind, or even designed as part of a comprehensive design process that accounts for normal Arctic operating conditions and requirements. Numerous unfortunate incidents have already been documented, such as the brake-boot problem, in which warfighters wearing VB boots are not able to drive vehicles, since their boots are so wide they hit both the brake and accelerator at once.

Arctic gear testing is also considered of paramount importance in Canada, due in no small part to previous lives lost to PPE seal failures. Lighter and warmer gear is always desirable, and researchers have found it helpful to incorporate CANSOFCOM input during testing. In the future, smart clothing technology and continued real-world testing are expected to improve the gear and clothing currently available. Marine Safety Technologies for Extreme Environments (MSTEE) uses National Research Council (NRC) facilities and expertise to conduct realistic testing in austere environments, and will be continuing to test clothing and sleep systems for improved field use.

Operator needs in the field are closely knit together with domain awareness needs, particularly the need for actionable, real-time information that could guide navigational decisions and reduce safety risks for operators.
Even in relatively normal conditions, Arctic operators face daunting risks and survival challenges, including animals that may damage equipment or pose threats to their wellbeing as well as severe wind-chill factors and exposure risks that can result in death or life-altering injuries.

**Operational Needs:** The Vermont National Guard 86th Infantry Brigade Combat Team, which is connected to the Army Mountain Warfare School, has sent soldiers to Finnish Cold Weather School, as well as to the Alps to train with Guerre Nordique. It also communicates regularly with soldiers at Fort Greely, Alaska on topics pertinent to mountainous and cold weather operations. Field advances like the ones they pioneer do not always wait for doctrine or DOTMLPF-P solutions, but prioritize field utility and applicability. Army Arctic military performance and survival is a problem of scaling solutions up to Army levels, not necessarily as meeting the challenge of operating in the Arctic at the SOF level of skill. In the field, the 86th Infantry Brigade Combat Team are experimenting with using rubber instead of metal tracks on vehicles, and recommend using snowmobiles and ski-jouring for rapid infantry movement (leaving snowshoes for more mountainous conditions.) In the field, Army National Guard representatives recommend using carbon monoxide sensors, practicing weapons truing in extreme cold, and incorporating sufficient training time.

They also report pronounced needs in terms of reducing heating source weights, providing more protein and glucose-loaded snacks packs, designing MREs and water-heating methods as part of an overall system, and to design heating methods for electronics. The stoves U.S. warfighters often use are diesel-hungry, weighing 120 pounds with fuel, and proving top-heavy once loaded into a sled. Canadians bring an SHA if traveling by snow-mobile with loaded trailers, but generally use an MSR WhisperLite, a Coleman Lantern, and a 2-burner Coleman stove that burns naphtha, which heats the tent to a desirable warmth. This system greatly reduces the overall weight, but increases the risk of fire and of carbon monoxide poisoning. These risks are countered by appointing a fire guard and bringing industrial carbon monoxide monitors.

- Radios and communication: Canadians have a Motorola radio that is more cold-resistant than what is often used by U.S. forces because it lacks an LCD screen. Liquid crystal freezes quickly, impairing use. Keeping Man Pack radios warm is critically important, and a solution for this is needed. Dagger NVGs do fairly well, but the cold is daunting to most electronics, and many options are too large to store inside jackets for warmth.

**Arctic Injury Patterns:** When injuries occur, Canadian research shows that operators tend to underreport them, both out of fear of being accused of weakness or unsuitability and of unfamiliarity with Northern conditions and norms. When allowed to bring their own kit, operators show a wide degree of variation in preparation, and some are underprepared for round-the-clock cold. Even prepared operators can easily be injured—an equipment failure, for example, may prompt an operator to remove his gloves, subsequently and rapidly leading to frostnip or frostbite. Canadian research records a relatively high incidence of frostbite injuries in troops during cold-weather exercises, some of which could have been life-altering without medical attention. These injury patterns are exacerbated by operator work-arounds that help them accomplish given tasks more quickly, but also expose them to potentially unacceptable injury risks. For example, mustering the dexterity needed to light a stove in field conditions is difficult, causing operators to remove their gloves and liners, thereby risking severe frostbite. Fielded goggles often display fogging issues, but going without goggles often leads to facial frostbite. Arctic operators routinely heat and chill themselves in relatively rapid cycles, posing risk, respectively, for overheating and for chilling/exposure. Sophisticated clothing layering systems are therefore necessary. Another prevalent injury pattern is back injuries incurred during rapid stopping on snowmobiles. Other issues occur with tent heating, food preparation, and venting—carbon monoxide, for example, builds up when cooking stoves are employed inside tents, but is difficult to detect. Cooking stoves
cannot always be used outdoors, given extremely cold temperatures and high winds. Should life-threatening injuries occur, CASEVAC or MEDEVAC options may be extremely limited, due to severe weather. During normal Arctic operations, solutions are already needed for keeping IV bags and other medical supplies warm.

- Recommendation: Develop sets of gear with multiple layers/options that can be tailored for the conditions at hand and are tested under realistic conditions

**The Meal Cold Weather:** Successful cold-weather feeding comes with its own ample set of challenges. The Meal Cold Weather is very different from other MREs, in that the water content must be extracted to reduce weight and the potential of freezing. The primary challenge when consuming the Meal Cold Weather in the field is generating hot water. The fuel tab used in the current Meal Cold Weather is classified as a hazardous material, complicating air lifts and logistics for Arctic supply chains. To side-step this issue, researchers at the U.S. Army Research Institute of Environmental Medicine (USARIEM) Natick Soldier Systems Center have been experimenting with corn-based fuels, which are not classified as hazardous fuels and are also suitable for packaging with foods. Issues still exist, however, with meal heaters that release carbon monoxide when heating cubes are used—the carbon monoxide can build up in operators’ bloodstreams, particularly if used in confined spaces such as unventilated tents, and can pose serious health risks. Alternative fuels can also have relatively short shelf lives, and may smell like alcohol upon opening or may exhibit other undesired characteristics.

Canadian troops carry summer and winter MREs, both of which cut down on the need for water to be heated by relying on a pressure cooker over a Coleman stove. U.S. MREs are designed to require about three times more water than Canadian ones do, so, when training together, the Canadian system is often preferred. Canadians also carry snack packs, and at every rest stop consume protein and glucose, often in the form of jerky and candy, supplemented by each soldier’s personal supplies of candy. These snack packs make a large difference in terms of energy and morale.

Canadians also have an innovative way to deal with the problem of transporting frozen water, which they accomplish by pouring water into cardboard boxes with very thick plastic linings, so that the frozen water cubes can be stacked, and the fire guard can chip off pieces to make water as needed. Nalgene flasks supplement these boxes, and are filled nightly by the fire guard.

- Recommendation: Develop systems with the same capabilities as Canadian ones, and develop an American snack pack for Arctic use.
- Recommendation: Develop better systems for water transport and heating.

**Research Advancements:** On its own soil, the U.S. has been advancing cold-weather research in the areas of thermal and mountain medicine, military nutrition at elevation, and high altitude performance factors. The Cold Injury Prevention Research Program, for example, examines ways to increase dexterity in the field by strategic nerve warming and forearm heating, as well as ways to boost blood flow with ingestible bioflavanols.

- Recommendation: Better support for troops operating in Arctic spaces could be built from a number of specific solutions sets. An improved Arctic sustainment package that is compatible with Canadian rations would be a good start. Additional measures would attempt to cut costs for Joint expeditionary exercises, maximize the benefit realized from such exercises, update aging and inadequate small unit support vehicles, and continue to seek efficient and efficacious ways to share Arctic-relevant survivability and performance expertise across the Services.
International collaborations offer a way to capitalize on science and technology advances in the Arctic for warfighter readiness and wellbeing as well as materiel advancements. Canadian leaders intent on rebuilding Arctic operational capabilities have already reopened the formerly shuttered Canadian Army Arctic Training Centre in Resolute Bay. Canadian science and technology also works on lighting, energy efficiency, wellbeing, sewage treatment, oil spill R&D and tracking, wing icing, bioenergy, fuel energy storage, and automotive and surface transportation.

**LC130 Issues:** Specific equipment, such as the LC130 airframe, can support missions and fulfill crucial supply roles by delivering fuel and supplies to field-deployed operators. The difference from a conventional C130 is the skis, which slows flying speeds by 30 knots and increases fuel burn by adding an additional 5000 lbs in weight. Skis permit ice and snow over ice landings, but are not developed for land/snow over land use.

As with many Arctic-specific equipment systems, the LC130 is attended by its own set of challenges. LC130s must ferry fuel for camp and expeditionary use in their own tanks, pumping the excess into ground storage (often a fuel bladder). Doing so frequently requires the laborious manual creation of a snow bridge for unloading. Any needed repairs take place in a hangerless environment, exposing technicians to potentially threatening conditions and adding cost and time to the repair cycle. Another challenge is the limited availability of Assisted Take Off (ATO) bottles—the bottles are no longer being commercially produced, and a mere 600-some are left. While the transition to NP2000 props will offer more thrust and decrease reliance on ATO bottles, the change will not eliminate the need for bottles completely.

Finally, LC130 operators must master flying in a variety of harsh and unpredictable conditions as the Arctic continues to change. Recent flying challenges have included heavy white-out conditions, increased fogging and icing, insufficient data to support informed navigational decisions, difficulties in landing on surfaces not already covered by ice and/or snow, the necessity—and attendant difficulty—of avoiding crevasses, overly thin ice, and other landing-zone hazards. Individually and in combination, these challenges can potentially interfere with LC130 abilities to complete supply runs or perform Search and Rescue (SAR) missions. In addition, more data is needed to develop SOLO (snow over land) capabilities, which will only become more essential as permafrost and ice continue to thaw and recede.

Though the challenges and desired capabilities reported at the workshop applied most pertinently to the Arctic, overcoming Arctic-specific challenges could translate into additional capability gains in the Baltics and North Korea.
Challenges Identified

- Lack of communication across all Arctic communities with shard interests
- Energy-efficient transport mechanisms
  - LC130 issues with radar navigation, ice fogging, snow-based landings, and landing on fragile ice

Recommendations Made

Communications and Collaborations

- Better communication and information-sharing practices
  - Engage with the US Army Extreme Cold Weather/High Altitude Symposium (to be held in Fairbanks 2019)
- Enhanced international collaboration to capitalize on investments

Operational

- Formal testing to uncover problem areas and challenge assumptions inherent in Arctic requirements documents
- Joint exercises; could involve multiple researchers conducting simultaneous testing
- Improvement of gear designed specifically for Arctic use
  - Gear testing in realistic conditions
- Improved power generation, storage, and transport
- Sophisticated layered clothing systems suitable for multiple conditions likely to be encountered in the Arctic
  - Inclusion of more interior pockets to keep gear close and sufficiently warm
  - Inclusion of fur ruff and option to use fur trim for gloves and boots
  - Better gloves and liners
  - Layered boot system; boot options that are more varied and suitable to the mission
- Advances in stoves, shelters, and materials to protect operators from unnecessary risks
- An improved Arctic sustainment package
  - Should be compatible with Canadian rations
  - Should offer protein and glucose-heavy snack packs
  - Better ways to heat meals and water
- Research on cold-weather-related fatigue and ways to manage/combat it
- Warming systems for electronics, or electronics small enough to fit within jackets
- Vehicular improvements for small unit support
- Better capacity to map crevasses and potential travel routes
  - Possibly using unmanned vehicles/robots
- Continued Joint exercises in more affordable ways
INFRASTRUCTURE

Needs: Arctic conditions require infrastructure able to withstand extreme cold, high snow loads, icing, and high winds as well as withstand unique challenges due to changes in permafrost conditions, thermal contraction and freezing precipitation. Infrastructure supporting Arctic security aims will need to be thaw-stable, energy efficient, and able to be rapidly constructed while requiring a minimal logistics footprint. It should also be retrofit-capable for repurposing and reconfiguring as needed. In the future, expeditionary infrastructure must maintain frozen ground conditions while still providing shelter and being rapidly deployable. More permanent structures should be erectable on site without the need for skilled finishers.

In the Arctic, needed materials are not always readily available, and shipping costs and durations can easily add orders of magnitude to project costs and completion times. The development of innovative materials that can be more locally sourced, are more resistant to rapid cycles of heating, chilling, and thawing, are retrofit-capable, and exhibit robustness over time would greatly aid Arctic development.

Potential solutions: Recent innovations include cold weather concrete, cellular concrete, flexible polyethylene piping, and engineered insulation, which collectively improve infrastructure’s ability to withstand sub-freezing conditions and demonstrate higher R-values. Retrofitted camp systems provide the greatest promise and value, and can be configured to the specific mission.

Cold weather concrete is being optimized, and is an example of innovation in materials development. Polyethylene piping has also been successfully used in Arctic conditions. Another promising emerging technology is Mobile Additive Manufacturing (MAMDFI), which enables onsite construction via 3-D printing, and could possibly use native materials. Rapid Installations Component Construction (RICC) are manufactured materials that do not require pre-assembly, and are therefore set up much more easily. A few examples, such as infrastructure at Fort Carson, demonstrate success in using materials that are finished elsewhere in pieces, reducing the time and complexity of assembly and finishing on-site. The Distant Early Warning (DEW) Line system of radar systems also relied on remotely assembled modules.

Infrastructure challenges still abound, however, as demonstrated, for example, by difficulties evidenced by the Air Force Basic Expeditionary Airfield Resources (BEAR) system in withstanding high winds, snow loads, and temperatures below -60°F, and by the inability of most off-the-shelf shelters to be readily deployable.

Additionally, permafrost can thaw under the warmth emitted by infrastructure, and must be kept chilled, particularly under concentrated weight, such as in the case of water towers. Alaskan permafrost shows a bottom-up thinning pattern than can be easily thermally disturbed, releasing water and possibly causing structural damage such as pipe breakage and irregular building settling. Permafrost environments exert demands that are both rigid and narrow, not leaving much of a margin of error for mistakes in infrastructure building and maintenance. Finally, expeditionary Arctic infrastructure is near-nonexistent, requiring a complete paradigm shift and substantial improvements before it can adequately support the warfighters.

The ice content within permafrost complicates the soil matrix, adding instability. Hybrid thermal siphon systems and seasonal cooling systems offer some solutions, but could be more adequately supporting by developing technologies such as combined subsurface analytic techniques like ground penetrating radar, DC electrical resistive tomography, conceptual modeling, and CC electrical resistive tomography. Further work could focus on quantifying the structure of frozen soils, understanding soil creep properties, and quantifying organic materials’ release and subsequent impact on groundwater. It is useful to point out that infrastructure failures in the Arctic can be severely exacerbated by factors such as liquid freezing at the breakage site, pipe
blockages, and the expense and relative impossibility of rapid repairs. Modular water treatment systems offer lighter, more flexible ways to recycle graywater and offer potable water onsite without relying so much on piping and infrastructure vulnerabilities that, if broken, may leave a unit waterless for weeks, if not months.

Arctic coastal erosion is occurring rapidly, and is not completely understood, as indicated by the fact that the degree of erosion observed by 2014 has already surpassed estimates for 2040. As sea ice coverage and volume decreases, wave height and severity is increasing, along with greater storm surge levels, all of which exacerbate erosion. Terrestrial warming means that coastlines are pre-warmed by the time storms and waves hit it, making soil even less resistant to erosional impacts.

Better modeling will enable a better understanding of erosion patterns and rates. Existing models, such as the Arctic regional basin model, local high-resolution models, and overall circulation and cline models for salinity and temperature could enhance erosion understanding and subsequent risk management decisions and planning for infrastructure relocation, siting, and resiliency.

Finally, power and energy sources are a huge challenge in the Arctic, and currently more than two million Arctic residents lack even a regional energy grid. Wise and innovative use of technology could yield locally-applicable solutions, such as harnessing renewable energy sources, using local biomass for heating, leveraging electrical storage, and using applications, such as specialty ceramic bricks, that are developed for specific conditions. Collaborations between ground grid and airline grid capabilities could offer a source of power, as could flywheels and adaptive mechanisms for changing surfaces. Energy generation systems can be two-sided, could be ocean deployed, and could capitalize on ‘stranded’ renewables, such as unlocking the energy generation potential of wastes, for example.
Infrastructure Recommendations Made

- Improved and more relevant infrastructure options
  - Rapid set up
  - Interlocking components
  - Composed of interchangeable components
  - Modular
  - Reusable
- Infrastructure methods and designs capable of supporting expeditionary troops
- A field-validated predictive model of thermo-chemical-mechanical erosion for the permafrost Arctic coastline
- Model predictions at scale, with high resolution and fidelity
- Adaptive building materials that are seismically capable and heat-containing.
- Comprehensive, updated environmental manuals and monographs for engineers’ use.
KNOWLEDGE EXCHANGE AND COLLABORATIONS

Workshop sessions repeatedly emphasized the pressing need for better communication channels, both within DoD and between DoD and its partners. In many instances, science and technology advances are not being comprehensively communicated to operators who could benefit from them. Researchers also have opportunities to advance Arctic-related science and technology much more rapidly and effectively, were they able to better maintain awareness of each other’s work and structure working collaborations.

While DoD communications and data-sharing does have room for improvement, the Workshop highlighted several ways in which useful communication and collaboration is already occurring.

Supporting Mechanisms: The National Science Foundation (NSF), for example, has long played an important role in supporting DoD research and missions. NSF improves DoD-related communication and collaboration at specific sites, including Thule, Raven, Kangerlussuaq, Toolik and Utquiaqvik. Synergistic collaboration allows NSF to assist Air Force training missions with LC130s and to otherwise provide asset support. Other NSF support activities include the manning of Thule’s deep water port, of oversight of the Thule High Arctic Atmospheric Observatory, and of the enactment of the Greenland Inland Traverse, a 740-mile tractor traverse for Thule resupply. NSF also contributes to the Arctic Digital Elevation Model (DEM) and collaborates on shared areas of interest, including transportation, energy, renewables, facilities, and autonomous instruments and operation. Much of NSF’s engagement with DoD interests can take place through the Interagency Arctic Research Policy Committee (IARPC) mechanisms, serving as a benefit to the overall Arctic research community.

➢ Recommendation: Increase the number and effectiveness of DoD-NSF collaborations to stretch dollars spent and maximize resources

Renewed U.S. Cold Weather Capabilities: The U.S. has previously exercised considerable polar research capabilities, particularly during the Cold War era. Foundational work done at the Cold Regions Research and Engineering Laboratory (CRREL) established a U.S. edge in ice core and permafrost studies, and CRREL researchers continue to contribute to materials science, heat-transfer capabilities, permafrost studies, and ice engineering. The facilities, however, experienced their highest use during the Cold War, and have since undergone an estimated $25 million loss in functional capacity. Restoring the facilities’ cold-weather testing and research capabilities is a proactive step toward adequately supporting Arctic science and will enhance U.S. capabilities in Arctic component testing and design.

➢ Recommendation: Allocate funding to renovate CRREL facilities and renew U.S. cold weather research capabilities

Canada: Science and technology is considered a critical element of Canadian national security and defense. Canada’s Defence Policy exhorts the nation to be ‘Strong, Secure, and Engaged,’ and Arctic engagement is considered a linchpin of enacting this policy, and through strengthening military capabilities and deepening engagement with Arctic residents. Canada will be building six offshore patrol ships and will be expanding research in hyperspectral imagery to support search and rescue work, in mining social media to track Arctic developments, in sensor buoy deployment, in developing autonomous underwater vehicles, and in increasing survival abilities for operators in Arctic environments. A significant area of investment is energy development and decreased dependency on fossil fuels in favor of alternative energy sources such as wind farms and photovoltaic cells.
Canadian-U.S. cooperation in science and technology is facilitated under the Critical Infrastructure Protection and Border Security (CIPABS) agreement. Collaborations, such as those currently between the DRDC and the U.S., are mutually beneficial, for example- icebreaker and vessel testing. Future projects could add to environmental characterization at operational scales for forecasting and technology optimization for remote use applications.

- Recommendation: Increase U.S.-Canadian partnerships when possible to leverage planned and existing Canadian investments in Arctic S&T

**Finland:** Finland’s military is uniformly prepared for cold weather missions and considers them a routine part of their operational mission set. Through the European Maritime Capabilities in the Arctic project, Finland is working on maritime polar capabilities, multi-nation cooperation on satellites, and risk and stress management. They recommend establishing an Arctic Knowledge and Data Management Cell, conducting regular Arctic education sessions, training, exercises, and evaluation, exercising Arctic domain awareness, and continuing Arctic preparedness through leadership courses and navigation training. Finnish expertise can offer lessons in snow operations, liquid natural gas use, improved tire technology, and the use of drones.

- Recommendation: Increase training exercises in concert with Finnish troops to gain expertise in cold weather operations

**Mechanisms for Collaborative International Research:** International Cooperative Engagement for Program for Polar Research (ICE-PPR) is a data and research exchange mechanism that enables international collaboration on situational awareness, human performance, platforms, and the environment, among other topics.

As part of ICE PPR, DoD is participating in a buoy-dropping program with the Danish Arctic Command at Thule to yield multi-year sensing data for improved meteorology and oceanography knowledge. The project offers benefits for everyone involved, giving Danish pilots opportunities to practice precision drops while also enabling buoy development and placement for optimal data collections.

In the future, ICE PPR will increase international military exchanges of scientific expertise, and will also facilitate joint training exercises. While many collaborations under ICE PPR will be Mil-to-Mil, the agreement permits academic institutions and other agencies to participate as well, using a military connection as a bridge into the agreement.

**United States Coast Guard:** USCG cadets are being trained in understanding environmental and geopolitical changes in the Arctic in preparation for future USCG operations and the USCG Arctic Strategy. The Naval War Arctic Circle has developed software to stress-test decision-making in the Arctic under different scenarios for cadets to practice resource allocation and incident responses before facing them “in the real world.”

**Risk Evaluation:** Using unconventional approaches to risk evaluation may hold merit. Anticipatory Operational Readiness methods incorporate uncertainty, add risks, and evaluate them through a risk assessment. Stochastic mathematical assessments can be assigned and can inform risk decisions and modeling. A distribution of answers through equation-based modeling can yield insights into a risk ensemble.

The private sector may offer helpful advice, and qualitative researchers can also map connections in the Arctic science and technology space. Limited objective experiment also offer insight via statistical analysis into capability-based assessments. A collaborative set of assessments would contribute to an overall understanding of Arctic possibilities. The approaches for risk management employed in the lower 48 may or may not be useful for Arctic-specific problem sets.
Final Observations: Workshop participants mentioned how rotational assignments could impair the retentions and transmission of Arctic-specific knowledge, which is difficult enough to gain in the first place. One of the final discussions revolved around how scientists should find better ways to engage operators directly instead of waiting for operators to push feedback up, and how science could also be viewed as a soft diplomatic tool for bolstering alliances and fostering goodwill as well as for possibly increasing the quality of communication in the Arctic research sphere. When possible, researchers and operators should gain Arctic experience and have opportunities to interact in a systematic and ongoing way.
BREAKOUT SESSIONS

After hearing a set of overall briefings on science and technology in the Arctic, participants broke into six different pre-assigned groups to discuss topics of specific interest, including Command Topics, Human Performance, Maritime, Domain Awareness, General S&T, and Permafrost. Participants were pre-sorted based on their areas of expertise—each group was pre-seeded 50% with experts in that domain and 50% with non-experts, to lend richness to the discussion and permit interdisciplinary problem-sharing and problem-solving. Each group was facilitated by a recognized research leader, and used a discussion guide to help each group address capabilities, challenges, gaps, and opportunities within their assigned topic area.

Command Topics Breakout Session
NORAD USNORTHCOM J-8

Lead: Dr. Hal Moore

Introduction: Command topics were those of relevance to decision-makers at the operational level, including discussion of priorities, policy, and emerging areas of concern.

Summary: At a high level, the group identified Arctic Expeditionary Warfare as the biggest emerging capability issue, closely followed by issues surrounding safety of navigation. Discussants agreed that policy needs to drive development, as science and technology alone will not adequately establish priorities and requirements. Science and technology could, however, point to tactical needs that could inform policy development.

Challenge Areas in the Space: Increasingly, operations will be happening in areas of high ice variability. More open water will be present, and ice presence and characterization data will be needed to ensure freedom and safety of navigation. More service members will likely occupy the Arctic, and must be adequately trained and outfitted. Survival, particularly for Arctic expeditionary warfighters, was ranked a very high priority as well as an area in which considerable knowledge gaps continue to persist. Already some warfighters are being exposed to Arctic conditions without full knowledge of how to best survive and thrive, or how to access and use the most recent capabilities and systems for power and communications.

➢ Recommendation: Fund research on factors enhancing human performance and survival in the Arctic. Develop surface mobility capabilities for rapidly changing permafrost.

Other gains will be won through developing Arctic-specific modeling and simulation datasets and techniques. The current situation—that of patchily surveyed landmasses, old bathymetric data, poor data normalization and coupling, and modeling assumptions used in the lower 48 without adequate consideration for how they may or may not hold true in the Arctic—needs improvement if warfighters are to improve and gain better skills in the region.

More highly developed sensors that are ruggedized for long durations of exposure to Arctic conditions and that can reliably transmit data (preferably autonomously) will aid in securing safety of navigation and will add to the overall picture of the Arctic that is still being developed. Better sensors onboard air frames and ships will contribute to more informed navigational decisions.

Identified Recommendations
• Survival studies and human performance research, including supporting equipment
  o Better mass casualty kits
  o Arctic-specific training for deployed warfighters
    ▪ Could include participation in Finnish/Norwegian exercise and alignment with EUCOM
• Enhanced safety of navigation
  o Improved bathymetric charts
  o Enhanced modeling and simulation
• Sensors to improve the quality and spread of observations that support maritime surface operations.
  o Data verifiability
  o USNORTHCOM advocacy for safety of navigation prioritization in the JROC
• Re-evaluation of equipment in current use
• Renewable energy development and integration
  o Emphasis on more usable and sustainable communications and power capabilities
• Ice-capable ships and refueling
• Improved cruise missile defense
• Reexamination of the Northern Warning System,
  o Reanalysis of its cruise missile defense capability
• Better preparation for an environmental disaster or accident involving tourism
• Mapping of potential flash points and scenario-based preparation that incorporate science and technology
  o Scenarios with undersea fuel bladders, sea gliders, etc.
• USNORTHCOM tasking of Services with requirements to develop or demonstrate Arctic-specific capabilities
• Methods for improved data verifiability
Human Performance Breakout Session  
Sullivan-Kwantes

Summary: Human performance issues span a gamut of specific challenge areas. A common thread, however, is the need for equipment, training, and medical approaches that are uniquely tailored to Arctic conditions, not just adaptations of non-Arctic approaches. Many of the challenges brought up could be addressed through well-planned, comprehensive exercise and events designed to simultaneously test and research human performance and cold-weather capabilities.

Performance: A chief factor determining human performance in the Arctic is the ability to maintain an appropriate temperature. Suitable homeostasis is a product of adaptation over time as well as gained skills. Either way, prepared troops are troops who have spent adequate time training in realistic conditions, and who have also been equipped with Arctic-suitable gear that is designed with realistic conditions of use in mind. Proper hand wear, footwear, and headgear is particularly important. Hand gear should be layered and should permit its wearer to fire a weapon, light a stove, or perform other basic tasks requiring dexterity without requiring gloves to be completely removed. Footwear needs to be appropriate to the task at hand—meaning no one boot may be sufficient—and should accommodate layering while also being compatible with any snowshoes or skis being used. Wearers do not typically wish to remove their socks daily, but compliance with proper wear guidelines would result in fewer injuries. Issues surrounding fatigue, cognition, and psychological concerns need to be more greatly researched. Expectation-setting and adjustment could be helpful focus areas for the future, as younger cohorts seem to suffer at times from technology deprivation when they can no longer be in steady contact with others online. Performers also may struggle with expectations—objectives generally take much longer to attain in the Arctic than in other environments. Finally, though they are usually placed low on the list of concerns, human performance issues related to standing watch and circadian rhythms need more attention.

Feeding: Warfighter operational needs are assessed every three to five years, using a field test that consists of taking a supplied ration to a cold-weather environment. The Defense Health Program (DHP) investments laid out for FY18/19 direct in a capabilities based assessment (CBA) to incorporate cold weather feeding. Heating food in Arctic conditions can feel oppressive to operators, due to the length of time required and discomfort incurred to get food hot enough to consume. Tired operators will likely turn to chocolate bars instead, and will also dehydrate themselves due to reluctance to leave sleeping quarters during the night to urinate.

Equipment: Equipment should not compromise warfighter safety. Tents currently being used may not be vented well enough or contain carbon monoxide sensors. Alternative fuels will help in multiple ways, by cutting down on operators’ exposure time and loads being carried. Communication system inadequacies continue to plague operators—the need for cold-weather batteries and reliable data transmission at high latitudes is still pressing. All equipment should be tested at extended periods of time at -30°F and below.

Medical Approaches: In the remote and austere conditions of the Arctic, comprehensive treatment and rapid evacuation for anyone injured may not be feasible. Teams should therefore be organized around medical needs that may arise, and should incorporate members with medical training or universal blood donors, for example.

Identified Recommendations
Better health protection and medical treatment
  o Wind chill charts tied to hypothermia risks
  o Hypothermia studies
    ▪ Action taken on injury patterns already recognized in the research, and on injuries due to lack of weather reports (and therefore sufficient preparation), to having insufficient gear, and to using gear incorrectly

Better PPE
  o Hand wear, footwear, and headwear
  o Boots that are compatible with snowshoes and skis being used, and that have removable inner components

Carbon monoxide detection, tent venting, or other ways to permit cooking inside shelters
  o Development of alternate cooking fuels
  o Development of more efficient stoves

Better sleep systems
  o Tents that accommodate cooking within them, and that do not overly warm permafrost they may be pitched upon
  o Caribou skin provides good ground insulation when used by special ops

Adequate equipment testing
  o Testing over a week at temperatures below -30°F

Communications systems
  o Access to local weather data

More realistic force protection guidelines

Requirements driven by Combatant Commands
  o Trainers can try to find gaps in plans in which a training objective can be developed
  o Combatant Commands drive the organization and equipment execution for the Services

Massive field events to test and research capabilities
The breakout group considered challenges to operating in Arctic maritime space, including challenges related to ice thickness and dynamics.

Their top three issues of concern were:

- Better coordination between S&T and Military
- Engagement of the science community in the early planning stages of Arctic military exercises to better facilitate scientific participation and overall benefit.
  - DoD could benefit from following NSF’s model
- Better engagement of sponsors with end users and S&T groups to jointly embark on possible solutions.

In the group’s views, the funder may direct S&T areas of focus, but may not be tightly connected with end user needs and preferences. The S&T community could also gain a better understanding of how the funding process works so they could participate in more pertinent ways. S&T researchers and industry members may need to cultivate better relationships with end users and military service members in pursuit of more applicable problem-solving and solutions. Communication and non-redundant scientific efforts would be aided by the use of a central clearing house for data.
Domain Awareness Breakout Session

Lead: Dr. Erin MacNeil

Summary: Domain awareness spans all environmental spheres, starting deep underwater and proceeding through the surface and air spheres into deep space. It can also incorporate 'noncanonical', evolving realms such as cyberspace and the electromagnetic spectrum. For maximal and most advantageous use in the Arctic, data that contributes to domain awareness should incorporate this span and be both timely and easily translatable. While security considerations can necessitate closed loop systems, open systems to integrate multiple data sets can lead to a common operating picture. Domain awareness advances when collaborators are supported and encouraged to work together. Strategies that encourage collaboration should emphasize open data sharing and the establishment of common architectures to gain efficiencies. Ultimately, such an approach will lead to stronger sensor development and better, more comprehensive domain awareness.

The Dynamism of Domain Awareness Needs: As human activity in the Arctic has been limited, historic data do not provide reliable foundations for modeling, a fact compounded by the rapid changes in the region. With available data and subsequent models marred by heavy limitations, ongoing modeling and data management efforts must consider the dynamic nature of current Arctic data. Updates need to be issued quickly and validated accurately to increase the strength of long-term observations, as the non-stationary nature of recent Arctic data patterns calls for faster response times and more update cycles.

Another important consideration for domain awareness is merging data streams and models from multiple dimensions of the domain. For instance, given their collective importance for awareness, rescue, and weather prediction, air and space domains could be more tightly incorporated into a unified Joint Services approach. Increasing understanding of where domain awareness needs are greatest and of how Services can jointly contribute to modeling, maintaining, and integrating broader and more comprehensive awareness from their respective domains is very important.

The breakout group also discuss the need to effectively communicate and link operational needs and priorities with leadership. Some of the most pressing needs concern those related to potential air threats from the Arctic corridor that could challenge the deep interior. Here, leadership has the opportunity to define and eventually fund priorities in the Arctic through policy. Possible approaches include establishing a Community of Interest (CoI) at the OSD level dedicated to Arctic concerns, which could help with information sharing and informing leadership of developing needs. Similarly, officially designating an executive agent tasked with carrying out Arctic priorities could also connect Arctic domain needs with leadership activities. Weather modeling, for example, is deemed extremely important in the Arctic by the operational community, but operators do not have a sense of the weight and importance DoD accords weather modeling in a larger sense.

Opportunities to foster better teamwork and leverage existing resources was also discussed as a means to improve capabilities for domain awareness and concomitantly reduce communication gaps and inefficiencies. Plenty of ongoing operations are in progress, which offer a low-effort pathway to capitalize on existing resources and reduce ad hoc efforts. For instance, Thule Air Force Base is currently used for weather research, and could serve as a venue to involve the Army and Navy in such work as well. More networking opportunities and chances to coordinate and synchronize efforts would continue to build a beneficial community for all involved.

International data sharing needs: Data sharing for exceptional domain awareness is difficult enough to do solely within the United States. The Arctic is an international space that demands international data sharing for mutual awareness and safety. Individual leaders may dictate where each country’s priorities lie, but economic
imperatives currently driving Arctic development and the need for safe navigation still present many opportunities for work across country borders.

**Top Identified Challenges**

- Dynamic climatology and oceanography changes.
  - Data paucity and insufficiency
- Broad scope and (undefined) nature of domain awareness
  - Need to include subsea/seabed/surface, air, space, electromagnetic and even cyber domains
- Systems are closed loops without outside sharing or integration
- Need for top-level leadership and strategy to direct Arctic efforts with authority

**Top Identified Opportunities**

- Capitalizing on existing resources:
  - Using opportunities that already exist to maximize returns on investments
  - Expanding use of existing facilities such as Thule Air force base
  - More communication and networking events to convene the broader community
  - Leveraging collaborations through existing frameworks, such as ICE-PPR
- Establishing common strategies, collective common architectures with common data models to support a common operating picture
- Establishment of a Community of Interest
**General S&T Breakout Session**

**Lead: Dr. Martin Jeffries**

**Summary:** The discussion revolved around identifying S&T needs for operators, specifically for DoD and USCG needs. Discussants agreed that terrestrial and maritime domains should generally be considered holistically, rather than in the separate manner in which they are usually addressed. They also identified various areas in which S&T could help solve Arctic-specific challenges.

**Data:** Data transmission, communications, and power remain serious challenges. Technology improvements such as robust autonomous instruments and observations network could assist with these needs, but will take dedication. These issues are particularly relevant within the field of domain awareness, which must by necessity be all-encompassing in nature, not restricted to the needs of individual vessels or aircraft.

Even when observational networks succeed in collecting useful data, reliably extracting this data is still a major capabilities need. A chasm separates scientists collecting data for their own purposes and those who need actionable data immediately in the field, artificial intelligence being a prime example. Currently being used to improve ship operations, AI still needs adequate observational data for successful modeling, and also needs an accurate understanding of operator needs. Huge, high-quality data sets that are currently very challenging to gather would be needed for state-of-the-art AI use and development in the Arctic.

As models continue to develop, validation and verification needs to maintain the same pace of development. The key, it appears, are better observations more reliably taken and more consistently transmitted into the right hands. Historic data may not inform current decision-making, but could still assist with overall model development and research, and should thus be preserved for future scientific access and ongoing validation efforts.

The equipment collecting the data is also important, and is not realistically obtainable off-the-shelf. Instruments for cold-weather use need rigorous testing. Sensors for domain awareness and data collection must be capable of transmitting under ice or water more quickly. Sensors are being improved, and vehicles such as drones, kites, UAVs, etc. do offer enhanced capabilities, but do not yet add up to a comprehensive, persistent communications network.

Understanding implications of the changing environment are also important, as in the case of the changing landscape of disease prevalence and transmission, due in part to permafrost thaw and the increasing possibility to transmit pathogens more easily. The environment is still rigorous enough, too, to obstruct efforts to care for sick or wounded warfighters.

Data sets are highly scattered under current conditions, and need to be normalized and more readily shared. Real-time meteorological data is a very pressing need for operators, and must incorporate new phenomena being observed, such as the increase in fog over open water.

Table-top exercise and war games are recommended to prepare for different various situations and to practice adaptable responses to unforeseen changes.
**Summary:** Across the branches of the services, DoD has extensive assets located on permanently frozen ground, or permafrost. Therefore issues related to permafrost due to climate warming are relevant. Several issues accompany warming and thawing permafrost, such as surface thaw settlement resulting in destabilized infrastructure, hindrances to overland mobility, altered surface and ground water flow, increased occurrence of slope failures, and increased rates of coastal erosion. However, there are no notable Army or Air Force requirements for terrestrial strategies in the Arctic. The attendees of this session agreed that not only is research needed to better understand the destabilized frozen terrains, but also Arctic Strategies are needed to help define the immediate needs and fill the current knowledge gaps.

**The Thawing Domain:** Domain Awareness includes the inherent implication that particular operations might be undertaken in that region at some time in the future. The frozen icy terrains of the Arctic present unique challenges that set it apart from the needs of mountain warfare, such as extreme temperatures and sunlight variations, extreme remoteness, and communication and logistics challenges. The warming Arctic environment, once steadfastly frozen, is thawing and rapidly changing, causing environmental changes that are difficult to predict. Ice-rich permafrost often suffers dramatic surface settlement upon thawing, which is destabilizing for infrastructure. The warmed terrain is now subjected to slope stability concerns especially in coincidence with increased precipitation events. The increased precipitation can cause rapid and dramatic thermo-erosion of ground ice and soil adjacent and under infrastructure, resulting in loss of capability or outright temporary failure. Lastly the deepening active layer, the near surface layer which thaws every summer, is now host to increased amounts of ground water, limiting the ability for overland mobility causing limits on operations and training.

The group identified that these issues complicate DoD mission sets in the domain, making it more difficult to conduct surveillance, defensive operations, search and rescue response, maintain presence, and provide support. In turn, it was identified that the lack of strategy and policy at the DoD level does not provide guidance on what the specific needs are, and the priorities that need to be addressed. Despite this, the group identified that specific challenges center on maneuver capabilities, enhanced infrastructure related to logistics and energy generation, alterations in logistics types and streams, and construction practices; all of which are dependent on stable terrain and founding materials. The increasingly thermally destabilized natural environment consists of geohazards such as permafrost thaw, flooding and coastal erosion; slope stability, icing events and wildland fires. Lastly the increased human presence via resource development; economic interests, and tourism causing expanding development, increasing logistical streams, increased waste and pollution issues, and overall technogenesis (built environment impacts to frozen terrain).

**Recommendations:** The group identified that the most important issue is identification of methods or technology gaps for DoD operations in a thawing frozen terrestrial environment. The operating modes and needs are required to be defined so experts can better understand how the changing environment may affect these operations. The group agreed one way to understand the issues is to conduct operations or training exercises that will allow the operators to identify method and technology gaps, providing experts with information to help solve the issue, and provide remedies to be further tested during exercise.
APPENDIX

COMPREHENSIVE LIST OF GAPS, NEEDED CAPABILITIES, AND POTENTIAL REQUIREMENTS MENTIONED AT 2018 WORKSHOP

Domain Awareness

- Need for Northern approach surveillance
  - Development of better sensors offering greater coverage
  - Need for data transmissions/communications devices not overly affected by aurora/geomagnetic factors
- High-fidelity models for atmosphere, ocean, and sea ice tracking
- Ice thickness surveying
- Ice tracking
  - Understanding of receding Arctic sea ice
  - Understanding sea ice extent
  - Ice crack sensing
  - Need to account for uncertainties in sea ice prediction
  - Real-time ice charts
  - Better model parameterization
  - Improved model fidelity, availability, and accuracy
- Better modeling
  - Higher definition
  - Real time modeling
  - Models with long-term prediction capabilities
  - Arctic-specific algorithms needed for surface ship sonar and for submarines
- Persistent sensing capabilities
- Data gathering for areas of the Arctic as yet unobserved
- UAV/UAS developments and other ways to conduct remote sensing
  - Secure data transmission
  - Partnerships with agile commercial entities
  - Practice flying/sensing under sustained, realistic conditions
- Tracking large mammals that may interfere with navigation or may be important to local hunting/fishing
- Better understanding of currents under waves
- More detailed and comprehensive bathymetric surveys
- Wildfire tracking
- Greater awareness of Russian air domain and activities

Operational Needs (People, Material, and Capabilities)

Communications + Domain Awareness

- Over-the-pole and long range communications capabilities
  - Over-the-horizon-radar
  - Radar functional in the ionosphere
  - Radar functioning in the 5-20MHz range
• Improved iridium communications
• Updates to Northern Warning System
• Ability to predict ice cracking
• Ability to better detect sea ice drift

Platforms

• Advancements in autonomous ships
• Ice hardening for vehicles
• More roads to underserved regions
• Updated LC130 capabilities
  o Shortage of Assisted Take Off bottles
  o More capabilities to deal with challenging weather
    ▪ Enhanced crevasse detection
    ▪ Digital elevation terrain data
    ▪ Ski over Land (SOLO) operations capabilities
• Technical solutions to increasing fog and icing issues
  o Ability to deal with iced-over lifeboat exhausts
• Data transmission and management capabilities
  o Solutions for getting actionable, update data on/off ships
• Ability to stage forward-operating bases

Clothing + Kit

• Modernized cold-weather clothing
  o Specialized for Arctic (instead of all-purpose) use
  o Thoroughly tested over sufficient time under realistic conditions
    ▪ Systematic instead of ad-hoc testing
  o Analysis of problem areas in terms of overall design
    ▪ Boot-brake interfaces
  o Fog-resistant goggles
  o Gloves permitting sufficient dexterity in the field while still offering enough warmth
  o Layered clothing systems to offer options for customization to the job and conditions at hand
    ▪ More pockets
    ▪ More inclusion of fur trims
    ▪ Removable boot liners
• Improved cold-weather feeding technology
  o Development of more-easily-heated MREs (using a pressure cooker, for example)
  o Development of a snack pack high in protein and glucose
  o Options for quicker heating of ice/water
  o Fuel tablets usable in the field
    ▪ Not classified as HazMat
    ▪ Don’t off-gas in confined spaces
    ▪ Reduced alcohol smell
    ▪ Reduced package bulkiness
Improved detection of, or ways to avoid carbon monoxide

- Proper communications equipment
  - Low-cost communications equipment
  - Ability to keep equipment (such as mobile phones) warm enough to function and small enough to fit in jackets
  - Communications devices with access to more satellite channels

**Training/Exercises + Support**

- Proper training/exercises
  - More Joint Arctic exercises
  - Strengthening Arctic engineering skillsets
  - Dedicated time for how long Arctic training takes
  - Work translating the experience of longtime practitioners into lessons learnable by more novice practitioners
- Move ICEx to February
  - Build ICEx and other expeditionary trips with rapid teardown capability and with small payloads
- Power needs for expeditionary deployment
  - Cold-weather batteries
  - Innovative means to store energy
  - Alternative energy use for expeditionary troops
- Logistics and supply chain management
- Ability to forward base 3000 troops
- More emphasis on human systems integration

**Infrastructure**

- Cold-weather materials development
  - Materials resistant to repeated heating and thawing
- Cold-weather structures for expeditionary use
  - Deployable/mobile
  - Resistant to condensation and to thawing ground
  - Able to handle heavy snow loads
- Infrastructure for water storage
- Infrastructure maintenance
  - Techniques for dealing with frozen soils and creep
  - Updated engineers’ manuals
- Facility upgrades
  - CRREL renovation
  - DEW line maintenance
- Understanding of coastal erosion/permafrost dynamics pertinent to infrastructure needs
  - Field-validated predictive models
Communications and Collaborations

- Allied partnerships
- Non-tactical data sharing between allies for navigational purposes
- A science and technology office or personnel member sited at Alaska Command (ALCOM)
- Increased DoD involvement in ALCOM activities
- Strong and clear idea of DoD priorities and requirements
- Increased participation in the Arctic Capability Advocacy Working Group
- Shared data and resources in, if possible, a central hub
- Bridges of knowledge-sharing and connection between university researchers and operators
  - Could leverage ICE-PPR
- Connect the S&T and policy communities more closely
  - Connect both communities with operators
- Engagement with end users
- More communication/shared exercises between data modelers and data collectors to normalize models, help communities work with data

PARTICIPANT-REPORTED NEXT ACTIONS

- Foster a stronger connection between military college and research centers
- Will set up icebreaker briefings with USNORTHCOM
- Define and enable partnerships with Canadian counterparts
- Advocate for Chilean participation in ICE-PPR and push for a robotic snow/ice challenge in Chile
- Will forge new partnerships and connect Coast Guard Center/TAC CO/DDG-95
- Involve the National Guard Arctic Interest Council

RESULTS

- As a direct result of the awareness raised during the workshop regarding naval surface forces transiting iceberg-infested waters, Commander SIXTH Fleet issued additional guidance regarding required reports and available meteorological and oceanographic information. Ships have continued to operate in these waters this summer and the Naval Ice Center confirms increased ship reports of icebergs as well as increased usage of ice and iceberg products in the region. – CDR Ruth Lane, National Ice Center
- Other results will continue to be tracked and shared.
2018 WORKSHOP PROSPECTUS

DoD 2018 Arctic Science & Technology Synchronization Workshop

16-18 May 2018
Cold Regions Research and Engineering Laboratory (CRREL)
72 Lyme Rd, Hanover, NH 03755

Description: The DoD 2018 Arctic Science & Technology Synchronization Workshop, which is co-sponsored by NORAD USNORTHCOM and the DOD Office of the Under Secretary of Defense for Research & Engineering (OUSD(R&E)) Human Performance, Training, and BioSystems (HPTB) Directorate, seeks to establish, align, and coordinate military-wide science and technology needs and requirements pertaining to the Arctic.

This workshop aims to further the DOD desired end-state for the Arctic, as laid out in the 2016 DOD Arctic Strategy: “a secure and stable region where U.S. national interests are safeguarded, the U.S. homeland is defended, and nations work cooperatively to address challenges.”[1] The workshop will support security and preparedness in the region, particularly by promoting the use of high-quality scientific information as an aid to decision-making, which was a principle highlighted in the 2013 National Strategy for the Arctic Region.

Other aims include:

1) To identify and strengthen opportunities to conduct collaborative DoD-wide S&T research with Arctic relevance
2) To inform the development of requirements for future DoD S&T research with Arctic relevance
3) To assess the infrastructure available to achieve DoD Arctic S&T objectives

The primary focus will be on military-specific S&T needs and requirements. Participants will include international partners, non-profits, academic centers, and federal agencies with a stake in the Arctic.

Objectives:
Workshop participants will emerge with:

- A greater knowledge of Arctic S&T advances with DOD relevance
- A stronger and more comprehensive network of national and international contacts and collaboration opportunities

DOD participants will make progress toward:

- A set of aligned and synchronized Arctic S&T requirements
- A roadmap of future directions for Arctic S&T development
RFI - 2018 Arctic Science & Technology Synchronization Workshop

Topics

Legal Context
This is a Request for Information (RFI), as defined in FAR 15.201(e), and is issued solely for information and planning purposes. This RFI shall not be construed as a Request for Proposal (RFP), Request for Quote (RFQ), a formal solicitation, or as an obligation on the part of the Government to acquire any product or services. Submission of any information in response to this RFI is completely voluntary, and costs associated with any submission shall not be reimbursed by the Government. Responses may be used to inform decision making by NORAD USNORTHCOM and the Office of the Assistant Secretary of Defense for Research and Engineering, ASD(R&E) regarding science, technology, research, and development with Arctic relevance. Evaluation letters will not be issued to respondents.

Background
The 2018 Arctic Science & Technology Synchronization Workshop, which is co-sponsored by NORAD USNORTHCOM and the Assistant Secretary of Defense for Research and Engineering, (ASD(R&E)), seeks to establish, align, and coordinate military-wide science and technology needs and requirements pertaining to the Arctic.

This workshop aims to further the DOD desired end-state for the Arctic, as laid out in the 2016 DOD Arctic Strategy: “a secure and stable region where U.S. national interests are safeguarded, the U.S. homeland is defended, and nations work cooperatively to address challenges.” The workshop will support security and preparedness in the region, particularly by promoting the use of high-quality scientific information as an aid to decision-making, which was a principle highlighted in the 2013 National Strategy for the Arctic Region.

Other aims include:
1) To identify and strengthen opportunities to conduct collaborative research and create beneficial relationships across military organizations
2) To connect operational communities with research communities in order to most effectively and efficiently address science and technology needs.

Participants will include international partners, non-profit, academic centers, and federal agencies with a state in the Arctic. The primary focus will be on military-specific S&T needs and requirements. The workshop builds on previous Arctic Science & Technology Synchronization workshops, which were sponsored by NORAD USNORTHCOM. The 2018 Arctic Science & Technology Synchronization Workshop will again be sponsored by NORAD USNORTHCOM, and will also include sponsorship from ASD(R&E) to help represent DOD-wide science and technology with Arctic relevance.

The workshop aims to: a) increase knowledge of S&T advances that are relevant to DOD interests and strategic/tactical needs, b) strengthen the Arctic S&T research network with regards to DOD applicability, c) make progress toward a set of aligned and synchronized Arctic S&T requirements, and d) support construction of a roadmap of future directions for Arctic S&T development with DOD relevance.
This RFI seeks input from the science and engineering communities to identify areas of Arctic-relevant S&T research that:
1. Are growing rapidly and/or encompass multiple domains; are the focus of substantial academic or private-sector research endeavors.
2. Strengthen existing Warfighter capabilities or promote new capabilities while conveying strategic and tactical advantage to U.S. forces.
3. Present opportunities for DOD awareness and engagement to promote force readiness and lethality while preventing loss of technological superiority.

Responses to this RFI may be reviewed by ASD(R&E), NORAD USNORTHCOM, the Cold Regions Research and Engineering Laboratory (CRREL), and associated DoD support contractors. Responses may be considered while formulating the agenda for this and upcoming Arctic S&T Synchronization Workshops, in informing the Department’s research focus, and in informing future engagement efforts. Any abstracts submitted will be considered for inclusion on the 2018 agenda.

Specific Information Requested
Responses to this RFI should be a) an abstract for presentations to be on the agenda for the 2018 DOD Arctic Science and Technology Synchronization Workshop, or b) Arctic S&T-relevant information that highlights important elements Workshop attendees should consider. Submissions should include:

1. Identification of the research area and research objectives.
2. Identification of subtopics and the technical and historical context of the rapid advance in each.
3. Author’s name, title, affiliation and contact information.
4. Disclosure of any conflict of interest with respect to the research area.
5. Discussion of the ways in which the research area is likely to experience advances over the next decade.
6. Discussion of how these advances are likely to impact Warfighter capabilities, U.S. technological superiority, or national security strategy.

Abstracts for presentations should run under 250 words in length and should propose inclusion in the DoD 2018 Artic Science & Technology Synchronization Workshop in one of the following formats:

i. Oral presentation of up to 25 minutes in length (5 minutes of which will be budgeted for subsequent questions and answers.)
ii. A panel session to present and discuss an Arctic-relevant theme for up to 90 minutes. (Presenters whose oral presentation submissions cluster into similar themes may be asked if they are willing to participate as part of a 3-4-member panel session).
iii. Posters for display and discussion

Abstracts are particularly encouraged in the following areas:

1) General Science & Technology
S&T research and development is proceeding rapidly in the Arctic, but so are developing needs. For this focus area, we invite applications on general Arctic S&T work, including research on ice sciences, hydrology, ecosystems, weather and climate monitoring and modeling, bathymetric mapping, clathrates, methane release, boreal sciences, atmospheric sciences, soil sciences, translational science, and prediction sciences.

2) **Domain Awareness**
Domain awareness is vital to the military mission of preserving sovereignty and ensuring communications in support of Arctic operations. For this focus area we solicit submissions related to command, control, communications, computers, combat systems, intelligence, surveillance, and reconnaissance (C5ISR), remote sensing, geospatial intelligence, radars, satellites, antennae, and space-based technology for readiness and domain/situational awareness.

3) **Key Capabilities: Operator/Infrastructure/Materiel Capabilities for Mission Achievement and Search and Rescue/Disaster Response**
To meet capabilities identified by DOD policies, S&T must further Arctic research and development that supports robust human performance, infrastructure resiliency, and materiel sustainability. For this focus area, please submit applications pertaining to operator community needs, materiel development and testing, human performance in the Arctic, infrastructure stability, search and rescue, disaster response, humanitarian aid, and operational mobility.

4) **Leveraging International and National Research Investments for DOD Arctic S&T Needs**
Rapid changes in the Arctic call for research collaborations, including collaborations across the DOD and with other federal agencies, to pinpoint S&T knowledge gaps, to leverage capabilities, and to establish and meet requirements. For this focus area we are interested in successful S&T collaborations between the DOD/Joint Services and civilian agencies, research or communications work conducted with indigenous communities, and research or exercises involving international collaborations.

**Presentation Proposal Review and Selection Process**
All solicited abstracts and information will be evaluated for:
A) Fit with DOD priorities identified in U.S. Arctic military policy
B) Ability to contribute to the overall portrayal of DOD-applicable Arctic science and technology accomplishments
C) Likelihood to foster productive discussions on DOD-relevant Arctic science and technology efforts and potential research gaps or capability needs
Notification of acceptance or rejection will be sent via email by mid-March, 2018. Please include an email address with your submission that will be viable at that time. Evaluation will be conducted by ASD(R&E) and NORAD USNORTHCOM. All proposals will be considered for:

Oral presentations, which are formal presentations including a brief question and answer session.

Moderated panel sessions comprised of 3-5 subject matter experts presenting on a similar topic. Proposals for panel sessions should identify a proposed moderator. In the event that individual presenters are requested to present as a group in a panel session, potential panelists will be asked if they have a preferred moderator.

Poster sessions, which consist of the information formatted in poster format. Presenters will post and remove their posters in the appointed areas at the appointed times, and will be expected to be present at session times to represent their work and answer questions.
# 2018 PROGRAM

## DoD 2018 Arctic Science & Technology Synchronization Workshop

16-18 May, 2018

Co-sponsors: NORAD-USNORTHCOM and DOD OUSD(R&E)
Location: U.S. Army Cold Regions Research and Engineering Laboratory

**15-May**

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<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>1630 - 1830</td>
<td><strong>Optional No-host Happy Hour</strong>&lt;br&gt; Salt Hill Pub (7 Lebanon St., Hanover, NH 03755)</td>
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**16-May**

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<th>Time</th>
<th>Event</th>
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<tr>
<td>0800 - 0900</td>
<td><strong>Registration</strong>&lt;br&gt; CRREL Main Auditorium (72 Lyme Rd., Hanover, NH 03755)</td>
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<tr>
<td>0900 - 0925</td>
<td><strong>Welcome and Introduction</strong>&lt;br&gt; Dr. Joseph Corriveau, Director&lt;br&gt; Cold Regions Research and Engineering Laboratory (CRREL)&lt;br&gt; &amp;&lt;br&gt; Dr. David Pittman, Director&lt;br&gt; Engineer Research and Development Center (ERDC)</td>
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<tr>
<td>0925 - 0930</td>
<td><strong>Greetings</strong>&lt;br&gt; Dr. Harrell Moore, Chief Technology Officer&lt;br&gt; NORAD USNORTHCOM J8 Science and Technology</td>
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<tr>
<td>0930 - 0955</td>
<td><strong>Opening Remarks</strong>&lt;br&gt; LTG Reynold Hoover&lt;br&gt; USNORTHCOM&lt;br&gt; &amp;&lt;br&gt; Mr. Dale Ormond, Principal Director, Research&lt;br&gt; OUSD(R&amp;E)</td>
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<tr>
<td>0955 - 1025</td>
<td><strong>Arctic S&amp;T Update: Lessons Learned and Emerging Challenges</strong>&lt;br&gt; Dr. Harrell Moore, NORAD USNORTHCOM J8</td>
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<tr>
<td>1025 - 1040</td>
<td>Break</td>
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<tr>
<td>1040 - 1100</td>
<td><strong>ALCOM Overview: Arctic Roles and Responsibilities</strong>&lt;br&gt; David Martin&lt;br&gt; ANR and ALCOM Deputy J5</td>
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<tr>
<td>1100 - 1120</td>
<td><strong>USNORTHCOM Overview: S&amp;T to Support Operations in Extreme Austere Environments</strong>&lt;br&gt; Mike Lupow, Sr. Intelligence Officer for Air, Maritime and the Arctic&lt;br&gt; NORAD &amp; USNORTHCOM J2</td>
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<tr>
<td>1120 - 1150</td>
<td><strong>DRDC Arctic Capability and Future Vision</strong>&lt;br&gt; Dr. Dan Hutt, Head - Underwater Sensing and Maritime Asset Protection&lt;br&gt; Defense Research and Development Canada, Atlantic</td>
</tr>
<tr>
<td>1150-1210</td>
<td><strong>U.S./Canada S&amp;T Cooperation - Improving Arctic Capabilities by Leveraging Our Strengths</strong>&lt;br&gt; Dr. James Millan, Director of Research - Ocean, Coastal and River Engineering&lt;br&gt; National Research Council of Canada</td>
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<tr>
<td>1210 - 1300</td>
<td>Lunch</td>
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<tr>
<td>1300 - 1400</td>
<td><strong>Arctic Maritime Operations Panel</strong>&lt;br&gt; Moderator: CDR Ruth Lane, Commanding Officer - Naval Ice Center&lt;br&gt; Panelists:&lt;br&gt; - CDR Al Siegrist, USS James E Williams (DDG 95)&lt;br&gt; - Mick Hicks, Chief Scientist - International Ice Patrol&lt;br&gt; - LT Emily Motz, Science Officer - Arctic Submarine Laboratory&lt;br&gt; - LT Lisa Hatland, XO - CGC KUKUI (WLB 203)</td>
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### LC130 Operations in the Arctic

**Maj Shay Price, 109AW**

#### 16 May (continued)

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<thead>
<tr>
<th>Time</th>
<th>Presentation</th>
<th>Speaker/ Institution</th>
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<tbody>
<tr>
<td>1440</td>
<td><strong>Expeditory Infrastructure - DoD Installations in the Arctic and Permafrost Engineering</strong></td>
<td>Kevin Bjella, Research Civil Engineer</td>
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<td>Cold Regions Research and Engineering Laboratory</td>
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<tr>
<td>1500</td>
<td><strong>Arctic Infrastructure Resiliency and Domain Awareness Research at UAA</strong></td>
<td>Dr. Aaron Dotson, College of Engineering</td>
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<td>University of Alaska Anchorage (UAA)</td>
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<tr>
<td>1520</td>
<td><strong>Arctic Coastal Erosion: Mechanistic Models for Coastal Hazard Evaluation</strong></td>
<td>Diana Bull</td>
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<td>Sandia National Laboratories</td>
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<tr>
<td>1540</td>
<td><strong>Realizing Reliable and Robust Energy Systems for the Arctic</strong></td>
<td>George Roe, Research Professor - Alaska Center for Energy and Power</td>
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<td>University of Alaska Fairbanks (UAF)</td>
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<tr>
<td>1600</td>
<td><strong>Arctic Materials Development and Testing with Operational Applicability</strong></td>
<td>Andy Margules, Science and Technology Advisor to US Army Alaska (USARAK)</td>
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<td>US Army RDECOM</td>
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<tr>
<td>1635</td>
<td><strong>NSF Research Support, Logistics, &amp; Operations in the Arctic: Leveraging Agency Partnerships to Advance Key Capabilities</strong></td>
<td>Dr. Jennifer Mercer, Program Manager, Arctic Research Support &amp; Logistics</td>
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<td>National Science Foundation</td>
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<tr>
<td>1700</td>
<td><strong>Icebreaker Social and Poster Session</strong></td>
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<td></td>
<td>CRREL Main Auditorium (72 Lyme Rd., Hanover, NH 03755)</td>
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<tr>
<td>0900</td>
<td>Overview: Arctic S&amp;T and the Arctic Domain Awareness Center</td>
<td>Maj. Gen. Randy &quot;Church&quot; Kee USAF (Ret.), Director, Arctic Domain Awareness Center University of Alaska</td>
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<tr>
<td>0930</td>
<td>All Domain Situational Awareness S&amp;T</td>
<td>Blair Passant Defense Research and Development Canada</td>
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<tr>
<td>0950</td>
<td>Research for Operational and Domain Awareness</td>
<td>Dr. Mark Moran, Technical Director Cold Regions Research and Engineering Laboratory</td>
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<tr>
<td>1010</td>
<td>Research for Operational and Domain Awareness</td>
<td>Dr. Robert McCoy, Director Geophysical Institute University of Alaska Fairbanks (UAF)</td>
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<tr>
<td>1030</td>
<td>Break</td>
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<tr>
<td>1100</td>
<td>Health Risks and Human Performance in the Arctic</td>
<td>Wendy Sullivan-Kwantes, Defence Scientist Defence Research and Development Canada</td>
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<tr>
<td>1120</td>
<td>Biomedical Performance Optimization in Cold Environments</td>
<td>Dr. Stephen Muza, Deputy Director Science &amp; Technology, Strategic Science Management Office US Army Research Institute of Environmental Medicine</td>
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<tr>
<td>1140</td>
<td>Multi-Purpose Individual Heating Technology for the Meal Cold Weather</td>
<td>Peter Lavigne, Combat Feeding Directive US Army Natick RD&amp;E Center</td>
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<tr>
<td>1200</td>
<td>Weathering the Cold: DND-NRC R&amp;D for Successful Arctic Operations</td>
<td>Geoff Stone, Soldier System Project Manager CANSOFCOM</td>
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<tr>
<td>1220</td>
<td>Lunch Talk: University of Alaska Arctic S&amp;T Research Collaborative</td>
<td>Maj. Gen. Randy &quot;Church&quot; Kee USAF (Ret.), Director, Arctic Domain Awareness Center University of Alaska</td>
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<td>1320 - 1340</td>
<td>Training and Troop Movement in the Arctic&lt;br&gt;COL Nathan Lord &amp; CPT Mathew Hefner, 86th IBCT (MTN)&lt;br&gt;Vermont Army National Guard</td>
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<tr>
<td>1340 - 1400</td>
<td>Synthetic Aperture Radar for Cold Regions Hazard and Surveillance Monitoring&lt;br&gt;Martin Thompson, Radar Intelligence, Surveillance and Reconnaissance Center&lt;br&gt;Sandia National Laboratories</td>
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<tr>
<td>1400 - 1420</td>
<td>Advancing the DOD Arctic Strategy: Recent Advances in UAS Technology and Regulations&lt;br&gt;Dr. Cathy Cahill, Director, Alaska Center for UAS Integration&lt;br&gt;Geophysical Institute, University of Alaska Fairbanks</td>
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<tr>
<td>1420 - 1440</td>
<td>Atmospheric Research for Arctic Regions at the Naval Research Laboratory&lt;br&gt;Dr. Neil Barton&lt;br&gt;US Naval Research Laboratory</td>
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<td>1440 - 1500</td>
<td>ONR Arctic and the Global Prediction Program and AMOS&lt;br&gt;Dr. Scott Harper, Program Officer, Code 32, Ocean Atmosphere and Space Research&lt;br&gt;Office of Naval Research</td>
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<td>1500 - 1520</td>
<td>Development and Utilization of the Navy’s Environmental Models to Support Polar Operations&lt;br&gt;Dr. David Hebert&lt;br&gt;US Naval Research Laboratory</td>
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<td>1520 - 1540</td>
<td>Overview: USCG Research and Development Center&lt;br&gt;Brian Dolph, Surface Branch Chief&lt;br&gt;USCG Research and Development Center</td>
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<td>1540 - 1600</td>
<td>Building a Modern Heavy Icebreaker: Balancing Security and Science Capabilities&lt;br&gt;CDR Kenneth Boda&lt;br&gt;USCG Cutter Forces, CG-751</td>
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<tr>
<td>1600 - 1620</td>
<td>Break</td>
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<tr>
<td>1620 - 1730</td>
<td>Small Group Breakouts: Facilitated Gaps and Solutions Discussions</td>
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<tr>
<td>1600 - 1830</td>
<td>Posters available for viewing (CRREL cafeteria)</td>
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<tr>
<td>1830</td>
<td>No-host Dinner at Jesse’s Steaks, Seafood &amp; Tavern&lt;br&gt;224 Lebanon St., Hanover, NH 03755</td>
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DoD 2018 Arctic Science & Technology Synchronization Workshop
16-18 May, 2018

Co-sponsors: NORAD-USNORTHCOM and DOD OUSD(R&E)
Location: U.S. Army Cold Regions Research and Engineering Laboratory

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<td>0730 - 0800</td>
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<td>1245 - 1400</td>
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18-May:

**Registration**
CRREL Main Auditorium (72 Lyme Rd., Hanover, NH 03755)

**Breakout Summaries**

**US Arctic Science and Policy**
Dr. Martin Jeffries, Program Officer
US Office of Naval Research

**Finnish Arctic Activities**
Lt Col Janne Jokinen, Assistant Defense, Military, Naval, and Air Attaché
Embassy of Finland to the U.S.A.

**Panel: ICE-PPR - International Challenges and Opportunities in Arctic Operations**
Moderator: Dr. Chris Bassler, Deputy Director, Office of the Senior National Representative, OPNAV-N94
Panelists:
- Vaughn Cosman, Director S&T Air 7, ADM(S&T), DRDC
- LCDR John Woods, Director of Experimentation for ICE-PPR, US Navy Reserve
- Lt Col Janne Jokinen, Assistant Defense, Military, Naval, and Air Attaché, Embassy of Finland to the U.S.A.

**Armchair Conversation:**
- **Arctic Access Considerations**
  Dr. Phil Brown, Deputy Chief, Joint Resources & Readiness Division
  NORAD & USNORTHCOM J74
- **Methodologies to Optimize Changing National Security Preparedness Demands Arising with Increasing Arctic Access**
  Diana Bull, Strategic Futures & Policy Analysis Dept.
  Sandia National Laboratories

**Facilitated Problem-Solving Discussion**

**Workshop Closing Remarks and Wrap-up**
Dr. John Farrell, Executive Director
U.S. Arctic Research Commission
& Dr. Joseph Corriveau, Director
Cold Regions Research and Engineering Laboratory